Size Optimisation of a car frame

Principles
Among other definitions, optimisation is a process which aims to improve the efficiency of a structure. There are a number of optimisation techniques such as topology, shape or size. This tutorial focus on the application of size optimisation.
In a size optimisation process, the properties of structural elements such as shell thickness or beam cross-section properties are modified to solve the optimisation problem. It is ultimately a mathematical problem but conceptually it can be defined by four entities:

• **Design Variable**: This is the structural property that is modified in order to solve the optimisation problem, i.e. shell thickness variation.
• **Objective**: This is the goal of the optimisation process, i.e. reduce the mass or increase stiffness.
• **Constraints**: These are conditions that the optimisation problem must satisfy, i.e. maximum stress allowed when reducing the thickness of a shell.
• **Responses**: These are model parameters that are of interest for the optimisation and they are used to reference the objective and the constraints, i.e. displacement is a design response which is used to define the maximum displacement limit.

Practical Case
During the design of a tubular structure for a racing car, the design team requires to reduce the weight of the racing car whilst maintaining its structural integrity. For this reason the design manager has decided to perform a size optimisation on the car structure. The optimisation is defined as follows:
• Design Variable: The tubular section radius (50 mm)
• Responses: Stress
• Constraints: Maximum stress (25 MPa)
• Objective: Reduce the mass (3 Tonnes approx)

![Fig 1. Car Structure](image)
Initially, the loading case considered is the static case where the racing car incorporates the pilot weighting 65e-3 Tonnes, the engine weighting 25e-3 Tonnes and full fuel tank weighing 15e-3 Tonnes. The tube material is made of steel (210000 MPa Young’s modulus, 7.85e-9 Tonnes/mm³ density and 0.3 Poisson’s ratio). The tube has a solid circular section of 100 mm of diameter. The only force acting upon the racing car is gravity, 9810 mm/s²

**Solution**

After the size optimisation is performed, the results are reviewed using the HyperWorks Desktop. The optimisation algorithm reduces the diameter of the beam section taking into account the stress constraint. The reduction of the diameter causes a reduction of mass which is the objective of this optimisation. This correlation is displayed in Fig. 2.

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**HyperMesh/optiStruct Size optimisation**

An initial car model is provided and using HyperMesh the optimisation problem is defined. Afterwards, OptiStruct will be used to perform the optimisation. Finally, all the results will be visualised using the HyperWorks Desktop.

**Phase 1 - Definition of the optimisation problem**

A finite element car model is supplied; the car is modelled using 1D elements. The optimisation problem requires to define the four entities described in the principle section.

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![Fig 2. Optimisation Results](image-url)
1 - Define size design variable, beam section diameter
2 - Define responses, mass and stress
3 - Define constraint, maximum stress (25 MPa)
4 - Define objective, minimise the mass of the frame

**Phase 2 - Car Optimisation**
The optimisation will be resolved using OptiStruct.

**Phase 3 - Extracting the results from the optimisation**
The HyperWorks Desktop will be used to post-process the results from the OptiStruct optimisation.

**OptiStruct results**
The optimisation reduces the weight of the car from 3 Tonnes to 0.6, a reduction of 80% of the mass whilst maintain the stress at required levels. Also, the beam section radius was reduced from 50mm to 20.02mm. This value demonstrated the validity of the optimisation method in order to design structures efficiently.
The weight of the racing car can be further reduce by selecting a different beam section such as hollow tubes. Why not try to change the beam section and see how lighter the racing car becomes.